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HALOFITELE

ASPECTE DE ANATOMIE ECOLOGICĂ

Editura Universităţii „Alexandru Ioan Cuza“ Iaşi

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Cuvânt înainte de T. J. Flowers

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ABSTRACT

Salinisation is currently one of the biggest problems facing Earth agriculture. In a continuous increase of world population, obtaining of salt tolerant crops represents a true priority. Halophytes have been defined as salt-tolerant plants having therefore, cellular, biochemical, physiological and anatomical mechanisms allowing them to survive in high salinity conditions.

This work represents an anatomical and ecological monograph of halophyte species from Moldova (North-Eastern Romania), representing the results of investigations conducted over many years. Thus, 26 taxa were investigated; these species belong to different botanical families and constitute a heterogeneous group of plants collected from different saline – some dry, others wet habitats.

Ecological anatomy approach involves a correlation between structure and habitat, between certain well-defined anatomical adaptations and some environmental factors such as salinity, soil moisture or dryness. In some cases, finding such correlations has been proved facile, while in other cases, some anatomical adaptations remain controversial, because their function is not fully elucidated.

In the introductory part of the book, we have discussed some theoretical issues related to definition and classification of halophytes and the relationship between halophytes and salt stress, the latter one being one of the most intensely studied in plant biology field. We are keeping open the question whether anatomical adaptations of halophytes are the result of formative effect of salts, salt stress damage or an expression of positive adaptation, allowing plants to withstand in hypersaline environments.

The proper part of the work refers to the histo-anatomical study of halophyte species. Ecological interpretations were made whenever possible, in concordance with the evidenced and discussed structure. As a general rule, we have seen that in most cases, histo-anatomical features are logically linked to environmental factors, thus being the effect of environmental factors.

We found that taxa included in the *Chenopodiaceae* (*Atriplex littoralis, A. prostrata, A. tatarica, Camphorosma annua, Halimione verrucifera, Petrosimonia oppositifolia, P. triandra, Salicornia europaea, Suaeda maritima*) show successive cambia phenomenon on vegetative axial organs (root, stem) level. Regarded by many authors as a structural anomaly, the connection of this phenomenon with salinity factor remains unclear. Although the interpretation of this phenomenon is very difficult to be done in ecological and adaptive direction, because here is almost a

completely lack in some studies, so we tried, as a hypothesis, to explain this phenomenon. We have assumed that additional cambia phenomenon might be a mechanism involved in regulation of salt content, thus having an adaptive and ecologic significance. Certainly, it is has been sometimes shown the fact that the intense lignification which is provided by the activity of successive cambia can be stimulated by salinity. Therefore, this could confer mechanical resistance of cells to high osmotic pressure of soil solution.

Halophyte species collected from wet habitats (*Aster tripolium* ssp. *pannonicus*, *Juncus grardi, Spergularia media*) present aerenchyma, especially in underground organs (rhizome, root). This feature is a common adaptation in species vegetating in such habitats, supplying the plant with oxygen during the possible hypoxia conditions.

Another interesting anatomical feature is a well developed endodermis, evidenced in some species (*Artemisia santonicum*, *Juncus gerardi*, *Lactuca saligna*, *Salicornia europaea*, *Suaeda maritima*, *Bolboschoenus maritimus*), on axial vegetative organs level. We have viewed this structure as a barrier that controls and limits the salt penetration in plant body.

Other adaptation, relatively common on halophytes and intensely discussed, is the shoot succulence. We have evidenced this feature, expressed by a water storage tissue and sometimes by a well-developed palisade tissue, in: *Salicornia europaea*, *Suaeda maritima*, *Petrosimonia oppositifolia*, *P. triandra* and *Spergularia media*. On halophyte species growing in wet habitats (*Suaeda*, *Salicornia*), the succulence ensures the erect position of plant and the potential dilution of toxic salts. In addition, the succulence can be induced and developed by chlorine ions as it is known that the two species listed above have been included in the chloruric plant associations. In xero-halophytes (*Petrosimonia oppositifolia* and *P. triandra*) the water storage tissues constitute, in the same time, a water reservoir needed in the dry seasons. Moreover, at these species, the succulence also facilitates the salt dilution, because in dry conditions salts become more concentrated in root zone.

Traheids occuring in succulent tissues of *Salicornia* are very interesting but also controversial structures. It is assumed that these tracheids are involved in plant water balance, salt tolerance, mechanical support and water or air storage. They are located among the palisade cells, approximately perpendicular to the epidermis, with no direct conection neither with epidermis, on the one hand, neither with vascular system of plant, on the other hand.

The vezicular, salt-secreting hairs (bladders) of *Atriplex tatarica* and *Halimione verrucifera*, evidenced in the leaf structure, are highly specialized structures, involved in the accumulation and subsequent removal of salts in excess. They are characteristic mainly in the *Chenopodiaceae*, and consist in a stalk-cell and a vezicular (bladder) cell, where salts are accumulated in order to be eliminated on leaf surface. The secretory pathway, chosen by many halophyte species (crynohalophytes) represents an important adaptive strategy in salt tolerant plants life.

Another adaptive mechanism related to the C_4 photosynthesis, is the so-called Kranz Anatomy configuration, in the leaf structure of some *Chenopodiaceae* species. Thus, we have described the atriplicoid sub-type on *Atriplex tatarica*, meaning that here is a sheath formed by izodiametric cells that form a layer more or less continuous around the vascular bundles. On *Petrosimonia opositifolia, P. triandra* and *Camphorosma annua* we have described the kochioid sub-type included in Kranz anatomy. This means, mainly, the following tissues dispozition: epidermis (with hypodermis on *Camphorosma*), external chlorenchyma (palisade tissue), internal clorenchyma (a layer of more or less cubic cells) and central, water storage tissue in which usually here a great vascular bundle is located. The two chlorenchyma tissues are arranged in two discontinuous layers, arround the leaf.

We have also evidenced bulliform cells (*Puccinellia distans, Juncus gerardi, Bolboschoenus maritimus, Carex distans*), at leaf epidermis level; these cells are mostly involved in leaves rolling in dry habitat conditions. But, apparently, their role is more complex and subtle than at first sight. Although they are considered a xerophytic character, we have evidenced them on hygro-halophyte species. In such a context, we think that here is not relevant to consider one single environmental factor, seen stable and fixed, but its fluctuation during one growing season. The plants listed above have been called amphibious halophytes, due to their ability to survive in dry soil conditions, and this real possibility requires, in addition, the presence of xeromorphytic features.

In general, as a result of our investigations, we can say that there are some obvious anatomical adaptations of halophytes, well defined, enabling them to survive in hypersaline environments. These features characterize the „obligatory" halophytes – species adapted to high salinity conditions, which are strictly restricted to salty areas, and are not found on other soil types than the saline ones. These observations allowed us to formulate a hypothesis regarding the „extreme" adaptations of halophytes to salinity. The most evident and „spectacular" characters, linked to halophilous profile

were observed on halophyte species adapted to higher salinity conditions (and usually on the species that occur only in high salinized areas).

Following our investigations and given interpretations, we have proposed a new system of halophytes classification, based on the relevance of anatomical adaptations correlated with the intensity of environmental factors (most oftenly, soil salinity). Thus, the *Chenopodiaceae* succulent species best adapted to high salinity conditions (*Salicornia*, *Suaeda*, *Halimione*, *Petrosimonia oppositifolia* and *P. triandra*) were nominated as extremohalophytes; in addition, because they grow only in very salinized environments, we apllied to them the term irreversible halophytes.

Atriplex littoralis, A. prostrata, A. tatarica, Bassia hirsuta, Camphorosma annua species, which have a large ecological spectrum and they are not so strictly related to increased salinity, were called by us as reversible halophytes. These species may also pass in less salinized environments.

The suporting, accidental or preferential halophytes which don't have histo-anatomical characters very clearly correlated to salinity factor were called mesohalophytes. They are more subjected to multiple influences of environmental factors, including soil salinity, but this is not the major factor inducing spectacular adaptations within this group of halophyte species. In the mesohalophytes group, the above mentioned amphibious halophytes could be included.

Our investigations and observations suggest that here is a relevant correlation between histo-anatomical features of halophytes and ecological factors of environments where they vegetate.

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Halofitele alcătuiesc un grup ecologic de plante, ce prezintă interesante adaptări anatomice – unele dintre ele mult discutate şi controversate în legătură cu factorul salinitate.

În acest context, prezenta monografie constituie o combinaţie inedită datorită modalităţii de abordare. Pe de o parte, este o lucrare de fitoanatomie, în sensul ideii fundamentate şi individualizate de Şcoala de Anatomie Vegetală ieşeană, iar pe de altă parte, o lucrare care depăşeşte cu mult simplele descrieri anatomice. Cartea are modesta, dar îndrăzneaţa intenţie de a promova un gen de anatomie modernă, care să rămână tangenţială cu preocupările interdisciplinare de ecologie, ecofiziologie şi implicaţii ale stresului salin – o tendinţă generală care domină momentan climatul ştiinţific mondial al biologiei vegetale.

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